METHOD AND APPARATUS FOR AUTOMATIC SELF-ALIGNING DOCKING OF A COUCH WITH A MAGNETIC RESONANCE IMAGING SCANNER

The following relates to the diagnostic imaging arts. It particularly relates to the docking and undocking of a couch or other movable subject support with a magnetic resonance imaging apparatus. The following relates more generally to rapid, safe, precise, and convenient transfer of a patient or other imaging subject into and out of various types of diagnostic imaging scanners such as magnetic resonance imaging scanners, computed tomography imaging scanners, nuclear cameras, positron emission tomography scanners, and the like.

In medical diagnostic imaging, an issue arises in the transfer of an imaging subject to and from the imaging apparatus. In many cases, the subject is disabled and unable to assist in the transfer process. In some instances it is important to preserve patient position.

Typically, the patient is placed on a wheeled patient couch or other movable subject support that is adapted to mechanically dock with the medical diagnostic magnetic resonance imaging scanner or other imaging apparatus. In one known approach, a locking mechanism that locks the couch to the imaging apparatus is triggered by operation of a brake pedal of the patient couch. Once connected, a conveyor belt of the imaging apparatus is linked with a patient supporting pallet or top of the patient couch, and the patient and pallet are transported into a magnet bore of the magnetic resonance imaging apparatus for imaging.

After the imaging session is complete, the patient and pallet are transported back and reconnected to the patient couch base. The operator disconnects the conveyor belt of the

imaging apparatus from the patient couch. The brake pedal is released, which also unlocks the patient couch from the subject support, and the patient couch is wheeled away.

These patient transfer systems rely upon substantial operator input and coordination to dock and undock the patient successfully. The couch is manually aligned and moved into the docking position, and the locking mechanism of the couch with the imaging apparatus relies upon accuracy of such manual alignment. Moreover, there is a substantial possibility of operator error causing patient injury and/or damage to the couch and/or imaging apparatus if, for example, the couch is undocked prior to disconnection of the conveyor belt linkage.

The present invention contemplates an improved apparatus and method that overcomes the aforementioned limitations and others.

According to one aspect, a docking assembly is disclosed. The docking assembly is connected to a movable subject couch for docking the movable subject couch with an imaging apparatus. Couch alignment surfaces mate with corresponding imaging apparatus alignment surfaces of a connecting region of the imaging apparatus to define a docked position of the movable subject couch with respect to the imaging apparatus. A docking sensor detects the movable subject couch approaching the docked position. A latch mates with the connecting region of the imaging apparatus. An actuator cooperates with the latch to bias the movable subject couch into the docked position in response to the docking sensor detecting that the couch has approached the docking position.

According to another aspect, a method is provided for docking a movable subject support couch with an imaging apparatus. The movable subject support couch is moved toward

the imaging apparatus. Responsive to the moving, a latch connected with the movable subject support couch mates with a connecting region of the imaging apparatus. The movable couch approaching a docked position with respect to the imaging apparatus is detected. Responsive to the detecting, the movable subject support couch is biased into the docked position using the mated latch as a first force anchor.

One advantage resides in reduced operator actions involved in subject docking and undocking.

Another advantage resides in a reduced likelihood of damage to the patient support and/or the imaging apparatus due to operator error in the docking or undocking.

Yet another advantage resides in improved docking and undocking reliability.

Still yet another advantage resides in self-alignment of the couch or other movable subject support with the imaging apparatus.

Numerous additional advantages and benefits will become apparent to those of ordinary skill in the art upon reading the following detailed description of the preferred embodiments.

The invention may take form in various components and arrangements of components, and in various process operations and arrangements of process operations. The drawings are only for the purpose of illustrating preferred embodiments and are not to be construed as limiting the invention.

FIGURE 1 shows a side view of a magnetic resonance imaging apparatus with a movable couch docked therewith.

FIGURE 2 shows a partial sectional view of the magnetic resonance imaging apparatus and docked movable couch of FIGURE 1.

FIGURE 3 shows a connecting region of the magnetic resonance imaging apparatus of FIGURES 1 and 2 that cooperates with a docking assembly of the movable couch in docking the movable couch with the magnetic resonance imaging apparatus.

FIGURE 4 shows an overhead perspective view of a lower portion of the movable couch including components of the docking assembly.

FIGURE 5 shows a perspective view from below of the lower portion of the movable couch shown in FIGURE 4.

FIGURE 6 shows a perspective view of a portion of the docking assembly including an actuator, connecting rods, mechanical fittings, a spring cartridge assembly, a divider plate, and latches.

FIGURE 7 shows a perspective view of one of the latches including a guide plate.

FIGURE 8 shows a perspective view of the latch of FIGURE 7 with the guide plate removed.

FIGURE 9 diagrammatically shows a state diagram of a state machine controller that controls the docking and undocking processes.

With reference to FIGURES 1 and 2, a magnetic resonance imaging apparatus **10** includes a housing **12** that encloses at least a main magnet which is preferably superconducting and cryoshrouded. The housing **12** defines a bore **14** inside which a subject is placed for imaging. Magnetic field gradient coils for spatially encoding the magnetic resonance signals are enclosed in the housing **12** or are arranged in the bore **14**, as are one or more radio frequency coils and other optional components that are cooperatively used to generate, tailor, and detect magnetic resonance signals of the imaging subject.

A motorized belt or chain drive **20** passes through the bore **14**. The belt **20** is linearly movable to position or move an imaging subject axially within the bore **14**. The motorized belt **20** includes a portion **22** extending beyond a first side **24** of the housing **12** to enable the subject to be positioned with a portion extending outside the bore **14** on the first side **24**.

On a second side **26** of the housing **12**, the belt **20** cooperates with a movable subject support pallet or couch top **28** of a couch assembly **30** to define a continuous motorized subject transport that extends on both sides **24, 26** of the housing **12**. Specifically, a coupling element **32** couples the belt **20** of the magnetic resonance imaging apparatus **10** with a subject support belt portion **34**.

The movable couch **30** is detachably attached to the imaging apparatus **10**. To enable the couch **30** to be moved when it is detached from the imaging scanner **10**, the couch **30** includes wheels **40**, rolling castors, or the like. One or more wheel brakes **42** are selectively operated to immobilize the couch **30**. Preferably, the couch **30** also includes a height adjustment mechanism **44** for vertically aligning the coupling element **32** with the belt **20** of the imaging apparatus **10**.

With continuing reference to FIGURES 1 and 2, and with further reference to FIGURE 3, the magnetic resonance imaging apparatus **10** includes a connecting region **50** that provides alignment and force anchoring for aligning and securing the movable couch **30** with the imaging apparatus **10**. In the illustrated embodiment, the connecting region **50** includes two latching blocks **52** on opposite sides of an electronic connector **54**. The electrical connector **54** provides for optional electrical communication between the imaging apparatus **10** and the movable couch **30**, for example to communicate sensor readings therebetween or to deliver electrical power and/or control signals from the imaging apparatus **10** to the movable

couch **30**. Each latching block **52** includes a camming surface **56** for camming a latch or other mating component of the subject support **30** onto the latching block **52**.

Placement of the two latching blocks **52** on opposite sides of the electrical connector **54** advantageously arranges the force anchoring symmetrically with respect to the imaging apparatus **10**. However, if the optional electrical connector **54** is omitted, a single centrally positioned latching block can be employed. Of course, more than two latching blocks can also be included to provide additional force anchoring points.

The connecting region **50** also includes a tongue **60** that extends away from the imaging apparatus **10**. The tongue **60** includes camming surfaces **62** for facilitating lateral alignment of the couch **30** with the imaging apparatus **10** during docking. The tongue **60** further includes alignment surfaces **64** disposed on the tongue edges that cooperate with corresponding surfaces of the docking assembly to define a docked position with the movable couch **30** in line with the bore **14**. A mounting plate **66** secures the connecting region **50** with the second side **26** of the imaging apparatus **10**. Alternatively, the connecting region **50** can be integrated with the housing **12**. Preferably, the connecting region **50** includes stops **68** that limit movement of the couch **30** toward the imaging apparatus **10** and limit skewing to assure that the couch **30** is in line with the bore **14**.

With continuing reference to FIGURES 1-3 and with further reference to FIGURES 4-8, a lower portion **70** of the movable couch **30** includes a docking assembly that cooperates with the connecting region **50** of the magnetic resonance imaging apparatus **10** to detachably secure the movable couch **30** with the magnetic resonance imaging apparatus **10**. The docking assembly includes alignment surfaces **72** with rollers or bearings **74** that cooperate with the alignment surfaces **64** of the tongue **60** of the connecting region **50** of the imaging apparatus **10** to define

the docked position of the movable couch **30** respective to the imaging apparatus **10**. The rollers or bearings preferably also serve as camming surfaces that cooperate with the camming surfaces **62** of the tongue **60** of the connecting region **50** to urge the movable couch **30** laterally toward the docked position as the couch **30** approaches the imaging apparatus **10**.

The docking assembly further includes latches **82** disposed at a forward end **84** of the couch **30** that detachably latch with the two latching blocks **52**. In the illustrated embodiment, there are two latches **82** corresponding to the two latch blocks **52**. An alternative embodiment with a single centrally located latch block will typically include a single corresponding latch, rather than the two latches shown.

In the illustrated embodiment, each latch **82** includes a hook **86** that is spring-biased to a closed position by a leaf spring **88**. (Best seen in FIGURES 7 and 8). The leaf spring **88** is secured to a guide block **90** at one end, and is preferably secured to the hook **86** by a fastener **92**. The guide block is secured to the lower portion **70** of the movable couch **30**. (Best seen in FIGURE 5). The hook **86** of each latch **82** pivots about a clevis pin **94** that in turn is connected with a clevis yoke **96** to allow the hook **86** to open in opposition to the biasing force produced by the leaf spring **88**.

The clevis yoke **96** is fastened to a guide rod **100** that slidably passes through the guide block **90**. A guide plate **102** is secured to the guide block **90** via fasteners **104**. (Note that the guide plate **102** is shown in FIGURE 7, and is removed in FIGURE 8 to show underlying components). The guide plate **102** includes a first narrow slot **106** that cams the clevis pin **94**, and a second wider slot **108** that cooperates with a camming pin **110** to guide opening and closing of the latch **82**.

The guide rod **100** of each of the two latches **82** connects with a divider plate **114** that distributes an actuator

force between the two latches **82**. As shown in FIGURE 6, ends of the guide rods **100** can connect to the divider plate **114**. Alternatively, as shown in FIGURE 5, each guide rod **100** can connect at an intermediate point such that the guide rod **100** also passes through a caster weldment of the couch **30** to assist in guiding and dividing actuator force between the two guide rods **100**.

The divider plate **114** in turn connects with a front connecting rod **120** via a pivotable clevis block **122** that is pinned to the divider plate **114**. The front connecting rod **120** includes a threaded opposite end that threads into a spring cartridge assembly **130**. A rear connecting rod **134** has a threaded end that threads into the spring cartridge assembly **130** and extends away from the forward end **84** of the movable couch **30** through a guide block **136** toward a rear end **138** of the couch **30**. The rear connecting rod **134** connects with another clevis block **142** that is pinned to a pivotable drive link **146**. The pivotable drive link pivots about a pivot **150** fixed to the weldment of the movable couch **30**.

An actuator motor **154** delivers the actuator force to the pivotable drive link **146** at an end of the drive link **146** opposite the pivot **150**. A second class lever is thus defined in which the load-coupling clevis block **142** is arranged between the applied force produced by the actuator motor **154** and a lever fulcrum defined by the pivot **150**. The hooks **86** are cammed apart during movement of the couch **30** and are biased by the leaf springs **88** onto the blocks **52**. To undock, the actuator motor **154** applies a force to the linkage which moves the hooks **86** apart, away from the blocks **52**. In one suitable embodiment, the actuator motor **154** is a battery-driven 24 volt self-locking linear actuator motor.

With continuing reference to FIGURES 1-8, the docking assembly further includes various sensors for sensing various

stages of docking and undocking. In the illustrated embodiment, these sensors include a start dock sensor **160** suitably embodied as a plunger switch that is activated or turned on (that is, plunger depressed) when the movable couch **30** approaches the docked position such that the plunger contacts a surface of the connecting region **50** of the imaging apparatus **10.** A flipper switch **162** similarly detects when the movable couch **30** is secured in the docked position, and when the couch **30** is substantially free from the docked position during undocking. A brake switch detects whether the wheel brake **42** is on or off.

Optical switch sensors **164** indicate a state of the drive link **146.** In a preferred embodiment, three drive link optical switch sensors **164** indicate whether the drive link **146** is in: (i) an undocked position in which the drive link **146** is pivoted toward the rear end **138** of the couch **30;** (ii) a docked position in which the drive link **146** is pivoted toward the front end **84** of the couch **30;** or (iii) a ready-to-dock position in which the drive link **146** is pivoted into an intermediate position between the front end **84** and the rear end **138** of the couch **30.**

With continuing reference to FIGURES 1-8 and with further reference to FIGURE 9, the docking assembly preferably includes a state machine controller whose state diagram **200** is schematically represented in FIGURE 9. The state machine controller is preferably embodied by a microprocessor or microcontroller disposed on the movable couch **30** that monitors the sensors and implements the state diagram **200.**

The exemplary state diagram **200** includes four states. In a ready-to-dock state **202,** the optical sensor **164** indicates the ready-to-dock position of the drive link **146,** and the start dock plunger sensor **160,** the flipper switch **162,** and the brake switch are off. In a docked state **204,** the optical sensor **164** indicates the docked position of the drive link **146,** the start

dock plunger sensor **160** and the flipper switch **162** are both activated, but the brake switch is off. A docked-and-braked state **206** is similar to the docked state **204** except that the brake sensor indicates the brake is on. In an undocked state **208**, the optical sensor **164** indicates the undocked position of the drive link **146**, the flipper switch **162** is activated, and the brake switch is off.

The exemplary state diagram **200** suitably implements a docking process that starts at the ready-to-dock state **202**. An operator rolls the movable couch **30** on its wheels **40** toward the connecting region **50** of the imaging apparatus **10**. During this movement, the camming surfaces **62** of the connecting region **50** of the imaging apparatus **10** contact and cam with the rollers **74** or other camming surfaces of the docking assembly to urge the couch **30** toward the docked position. Similarly, the hooks **86** of the latches **82** contact the camming surfaces **56** of the latch blocks **52** of the connecting region **50** and cam open against the biasing force exerted by the leaf springs **88**. As continued movement of the couch **30** moves the hooks **86** past the camming surfaces **56**, the hooks **86** close onto the latching blocks **52** due to the biasing of the leaf springs **88**.

Continued movement of the couch **30** toward the docked position causes the start dock plunger **160** to be pushed in, triggering a transition from the ready-to-dock state **202** to the docked state **204**. The actuator motor **154** is driven to pivot the drive link **146** from the ready-to-dock position to the docked position. This movement produces an actuator force $\mathbf{F_1}$ pulling on the rear connecting rod **134**. Initially, the actuator force $\mathbf{F_1}$ transfers through the rear connecting rod **134**, the spring cartridge assembly **130**, and the front connecting rod **120**, and is distributed by the divider plate **114** and the guide rods **100** to the two latches **82**. Thus, the actuator force $\mathbf{F_1}$ is a tensile force acting between a rear force anchor point corresponding to

the motor **154** and the drive link **146**, and a front force anchor point defined by the connection of the latches **82** onto the latch blocks **52**.

The tensile actuator force $\mathbf{F_1}$ draws the movable couch **30** into the docked position. Once docked, the motor **154** continues to operate to transfer and store a predetermined amount of mechanical energy in the spring cartridge assembly **130**. In a preferred embodiment, the spring cartridge assembly **130** is loaded to about 55 kg. Once the spring cartridge assembly **130** is loaded to the desired value, the motor **154** ceases operation.

Thus, when the motor **154** ceases operation the movable couch **30** remains biased and secured in the docked position by the loaded spring cartridge assembly **130**. The docked state **204** is indicated by the optical sensors **164**. To ensure the movable couch **30** is secured, the user is preferably prompted by a display or other indicator to engage the brakes. The operator engages the wheel brake **42**. Engaging the wheel brake **42** activates the brake switch and places the docking assembly into the docked-and-braked state **206**.

Once docked and braked, the operator connects and locks the belt coupling element **32** to the belt **20** of the imaging apparatus **10**. Once the connection is sensed, a lock which locks the subject pallet or couch top **28** to the couch **30** is released. The belt **20** transfers the subject pallet **28** into the magnet bore **14** of the imaging apparatus **10**. The operator causes the imaging apparatus **10** to perform selected magnetic resonance imaging operations on the subject, and transfers the subject back to the movable couch **30** via the linked belts **20**, **34**.

Once the pallet **28** is locked to the couch **30**, the operator can initiate undocking by decoupling the coupling element **32** and releasing the wheel brake **42**. Preferably,

transition from the docked-and-braked state **206** to the undocked state **208** is initiated by release of the wheel brake **42**. However, the transition preferably also is contingent upon a tabletop sensor **212** (operatively represented in FIGURE 9) indicating that the conveyor belt coupling element **32** is unlocked and the pallet **28** is locked to the couch **30**. This reduces the likelihood of damage to the conveyor belts **20, 34** or the coupling element **32**.

To undock, the motor **154** operates in a reverse direction to pivot the drive link **146** from the rearward docked position to the forward undocked position. This exerts an actuator force $\mathbf{F_2}$ on the rear connecting rod **134** directed toward the front end **84**. Initially, the actuator force $\mathbf{F_2}$ transfers through the rear connecting rod **134** to the spring cartridge assembly **130** to unload the spring cartridge assembly **130**. That is, in the exemplary embodiment the 55 kg stored in the spring cartridge assembly **130** is unloaded.

Once the spring cartridge assembly **130** is unloaded, the actuator force $\mathbf{F_2}$ transfers through the rear connecting rod **134**, the spring cartridge assembly **130**, and the front connecting rod **120**, and is distributed by the divider plate **114** and the guide rods **100** to the two latches **82**. The actuator force $\mathbf{F_2}$ drives each hook **86** forward. During this forward motion, the clevis pin **94** cams in the first narrow slot **106** and the camming pin **110** cams in the second wider slot **108** of the guide block **90** to guide the hook **86** into an open position against the biasing force of the leaf spring **88**.

When the drive link **146** reaches the undocked position as indicated by the drive link optical switch sensors **164**, the latches **82** are retained in the open position. The operator can then move the couch **30** away from the imaging apparatus **10**. The movement draws the opened latches **82** past the latch blocks **52** of the connection region **50** of the imaging apparatus **10**.

Continued movement causes the flipper switch **162** to deactivate, indicating that the latches **82** are clear of the latching blocks **52**.

Deactivation of the flipper switch **162** initiates a transition from the undocked state **208** to the ready-to-dock state **202**. To make this transition, the motor **154** moves the drive link **146** from the undocked position to the intermediate ready-to-dock position. The movement transfers through the rear connecting rod **134**, the spring cartridge assembly **130**, and the front connecting rod **120**, and is distributed by the divider plate **114** and the guide rods **100** to the two latches **82**. The actuator force $\mathbf{F_2}$ holding the hooks **86** open is released so that the closing bias provided by the leaf springs **88** causes the hooks **86** to be biased into the closed position.

Docking and undocking of the movable couch **30** with the exemplary magnetic resonance imaging apparatus **10** is described herein. However, those skilled in the art can readily adapt the described docking assembly to perform docking and undocking of a patient couch or other movable imaging subject support with other types of magnetic resonance imaging scanners, or with a computed tomography imaging apparatus, a nuclear camera, a positron emission tomography imaging apparatus, a radiotherapy apparatus, or the like.